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50X1-HUM

CONTROL OF THE THICKNESS OF ELECTROPLATED COATINGS
BY AN ELECTRICAL METHOD

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/Figures referred to are appended./

Realization of the control of the thickness of electroplated coatings is of considerable significance.

The so-called drop method of control is in wide use at present.

The shortcomings of this method are: the necessity of having a number of solvents for each type of coating, the length of the test, spoilage of the surface being studied, and the high degree of error in testing relative to the accuracy of calculating the time of action of the drop, accuracy of preparing a solvent of determined concentration, the temperature of the surrounding medium, and other factors. All this may lead to an error of 100%, particularly in the testing of coatings of less than 5 μ.

Other methods for determining the thickness of coatings (gravimetric and optical) are purely laboratory methods and can not be recommended for mass control use.

Magnetic thickness gages, whose principle of action is based on measurement of the force pulling a permanent magnet from a ferromagnetic piece with a nonmagnetic coating, are little sensitive to thin coatings.

Other devices, based on the measurement of secondary emf of a transformer with an open magnetic circuit in which the resistance of the magnetic conductor varies relative to the thickness of the nonmagnetic gap, i.e., the electro-plated coating, also are not in widespread use. Experimental models of these devices demonstrated low sensitivity to very thin coatings. In addition, the devices are designed only for measuring coatings on parts made of ferromagnetic materials and having a certain configuration.

- 1 -   CONFIDENTIAL

CONFIDENTIAL

50X1-HUM

The measurement of coating thickness with the aid of high-frequency eddy currents is based on the different specific electrical conductivities of the coating metal and the base metal.

If a bridge circuit is used containing the pure coating metal in one arm and the part, coated with the same metal, in the other arm, then by selecting the necessary supply frequency of the circuit and varying it evenly, the moment at which the circuit balance is distributed may be observed.

The depth of eddy current penetration depends on the frequency; therefore, while the depth of penetration into the metal is small, the eddy currents in both arms are propagated in the metal of the coating and the circuit remains balanced. The depth of penetration is disturbed as the frequency is changed. The circuit balance is disturbed at some frequency, and it then becomes possible to judge the thickness of the coating layer. Apparatus operating on this principle is quite complex and there are no industrial models of such devices.

The authors have developed an electromagnetic thickness gage, Type ZTMP-48, based on the secondary-emf-measurement principle and using a control plate. The apparatus facilitates highly accurate determination of any thickness of a coating (except nickel) from 2 to 60 μ.

Figure 1 shows the circuit diagram of the apparatus. The sensitive element of the device -- the transmitting element D -- is a transformer with an open magnetic circuit and, consequently, a variable transformation ratio during measurement. The magnetic circuit of the transformer-transmitting element makes contact with the ferromagnetic part, 1. The thickness of the nonmagnetic coating, 2, on this part determines the resistance of the entire magnetic circuit.

The value of the magnetic resistance of the coating layer is quite large in comparison with the resistance of the magnetic materials.

Mere measurement of the transmitting element's secondary emf does not give sufficient sensitivity; therefore, a differential measuring circuit is used. The secondary voltage of the transmitting element is rectified on the Graetz bridge, M_2, using copper-oxide rectifiers, and is connected so as to oppose the voltage rectified on bridge, M_1. The galvanometer G measures the difference in these voltages and is graduated directly in microns of thickness of the electroplated coating. The indicator has two scales, one up to 35 μ and the other from 30 to 60 μ.

The switch, P, is included in the circuit for changeover to measurement on the second scale. The switch disconnects shunt resistors Sh_1 and Sh_2 of the indicator, increasing its sensitivity, and alters the resistance of the rheostat, R_4, so that the null point is shifted sharply to the left and the base position of the needle is at 30 μ.

To reduce the effect of circuit voltage fluctuations on accuracy of measurement, a ballast resistor, b, is included in the circuit. The ballast resistor stabilizes the voltage within ± 20% of the fluctuations on the primary side. The indicator is a needle device with a sensitivity of 100 μa on the scale. The entire circuit is supplied from a 220-v ac line.

The variable transformation ratio, which changes linearly with the thickness of the coating, is, in absolute value, a complex function of the value of the gap, geometrical configuration, dimensions of the magnetic circuit, and the degree of saturation of the iron.

The value of the secondary voltage may be established experimentally. The magnetic circuit shown in Figure 2 gives optimum sensitivity and has the advantage of small size.

- 2 -

CONFIDENTIAL

CONFIDENTIAL

50X1-HUM

To be able to use the apparatus for measuring any type of coating (except nickel) on any metal, a method involving indirect measurement with the use of a control plate is employed. The possibilities for application are thus extended beyond ferromagnetic materials alone.

The control plate is a 40-mm square, 4-5 mm thick, with a well-finished surface. The material used for the control plate may be any untreated steel. There is an opening in the upper part of the plate for a rack.

The control plate is placed in the electroplating bath along with a batch of production parts.

As is known, the thickness of the coating does not depend on the material in the parts being covered; nor, in most cases, does the thickness depend on the form of the parts. By carrying out measurements on the control plate it is possible to find out the thickness of the coating on the production parts. The control plate must be placed in the bath under exactly the same conditions as the production parts.

To reduce error in the apparatus, the measuring plane of the transmitting element and the surface of the control plate are thoroughly processed, since rough places in the surfaces will prevent the magnetic circuit of the transmitting element from lying flush against the plane of the plate. This would be equivalent to increasing the coating layer. To assure the desired quality of the measuring plane of the transmitting element, the surface of the plane is not finished until after the element has been completely assembled.

The graduation, and the testing of the operation of the apparatus, is done by measuring the thickness of the control plate on an optimeter before and after coating. Half the difference between these readings gives the true value of the coating layer.

The control plates are used for an unlimited time, since any coatings, after their thickness has been determined, can be removed galvanically. To avoid production bottlenecks which might be caused by a lack of control plates, 50-100 plates should be prepared for each apparatus.

50X1-HUM

Measurement error on the apparatus does not exceed 2μ. Thicknesses from 2 to 60μ can be measured, and the process takes about 1 to 2 seconds.

Data on the Electrical Units in the Apparatus

1. Transformer T_1, W_1 -- 2,000 turns of PE wire, $\emptyset$ 0.02; W_2 -- 200 turns of PE wire, $\emptyset$ 0.8; core, Sh 19; pack, 2 cm.

2. Transformer T_2, W_1 -- 150 turns PE $\emptyset$ 0.8; W_2 - W_3 -- 2,000 turns PE $\emptyset$ 0.12; core, Sh 10; pack, 1.5 cm.

3. Ballast resistor, Type 1B 10-17.

4. Transmitting: W -- 500 turns PE $\emptyset$ 0.06; W -- 2,000 turns PE $\emptyset$ 0.06; for magnetic circuit dimensions, see Figure 2.

5. Resistance R_1, R_2, and R_3 are adapted to the characteristics of the copper-oxide rectifiers.

6. The Graetz bridges have four copper oxide elements each, Type 209 VK-1.

7. The needle indicator is Type M-494.

- 3 -

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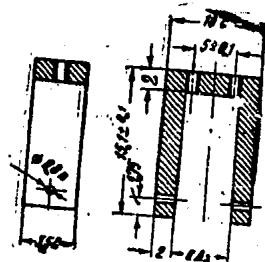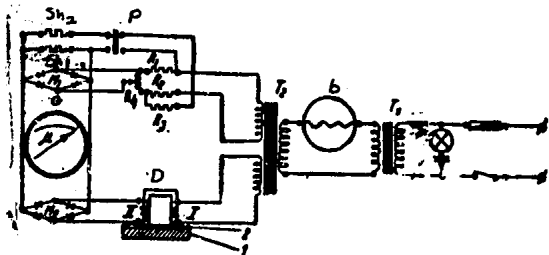50X1-HUM

Figure 1.　Circuit Diagram of the ZTMP-48 Apparatus

Figure 2.　Magnetic Circuit of the Transmitting Element

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